# Physics 129A

Introduction to Particle Physics

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3 Evans Tu -Th 11:00AM-12:30 PM
Disc. 41 Evans Tu 2:00PM-3:00 PM

Office Hours:
TBA
Today 2:00-4:00 PM

Short Discussion Section today to get acquainted.

# Draft Syllabus:

- Overview of the history of Particle Physics
- Review of Relativity and Quantum Mechanics
- Introduction to Nuclear Physics
- Symmetries in Nuclear and Particle Physics and the Quark Model
- Relativistic Quantum Mechanics
- Feynman Diagrams
- QED
- QCD
- Weak Interactions
- Gauge Theories and the Standard Model
- Modern Topics: neutrinos, particle astrophysics,…

## Suggested Texts:

Introduction to Elementary Particles -- David Griffiths

Introduction to High Energy Physics -- Donald H. Perkins

Quarks & Leptons: An Introductory Course in Modern Particle Physics -- Francis Halzen and Alan D. Martin

A longer list of textbooks will be provided.

Reading assignments from the texts and journals will be suggested.

Read Chapter 1 from Griffiths for this week.

## Course Work

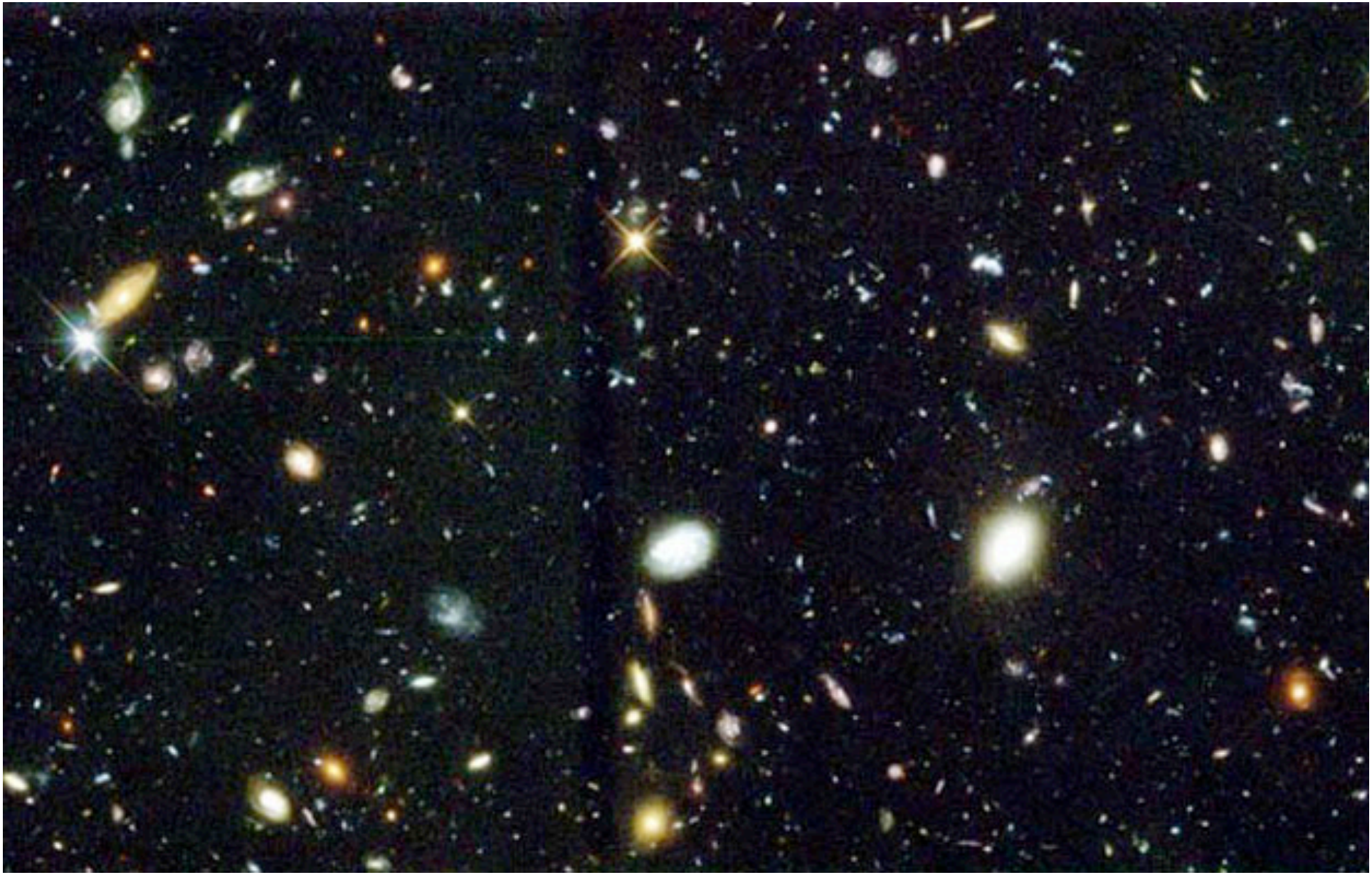
- Homework (about 10 problem sets)
- One Midterm (in class)
- One Short Report on a Journal Article or Topic (maybe)
- One Final Examination (in class or take home?)

## Old view:

The Goal of "Particle Physics" is to understand the nature of matter and its interactions at the most fundamental level.

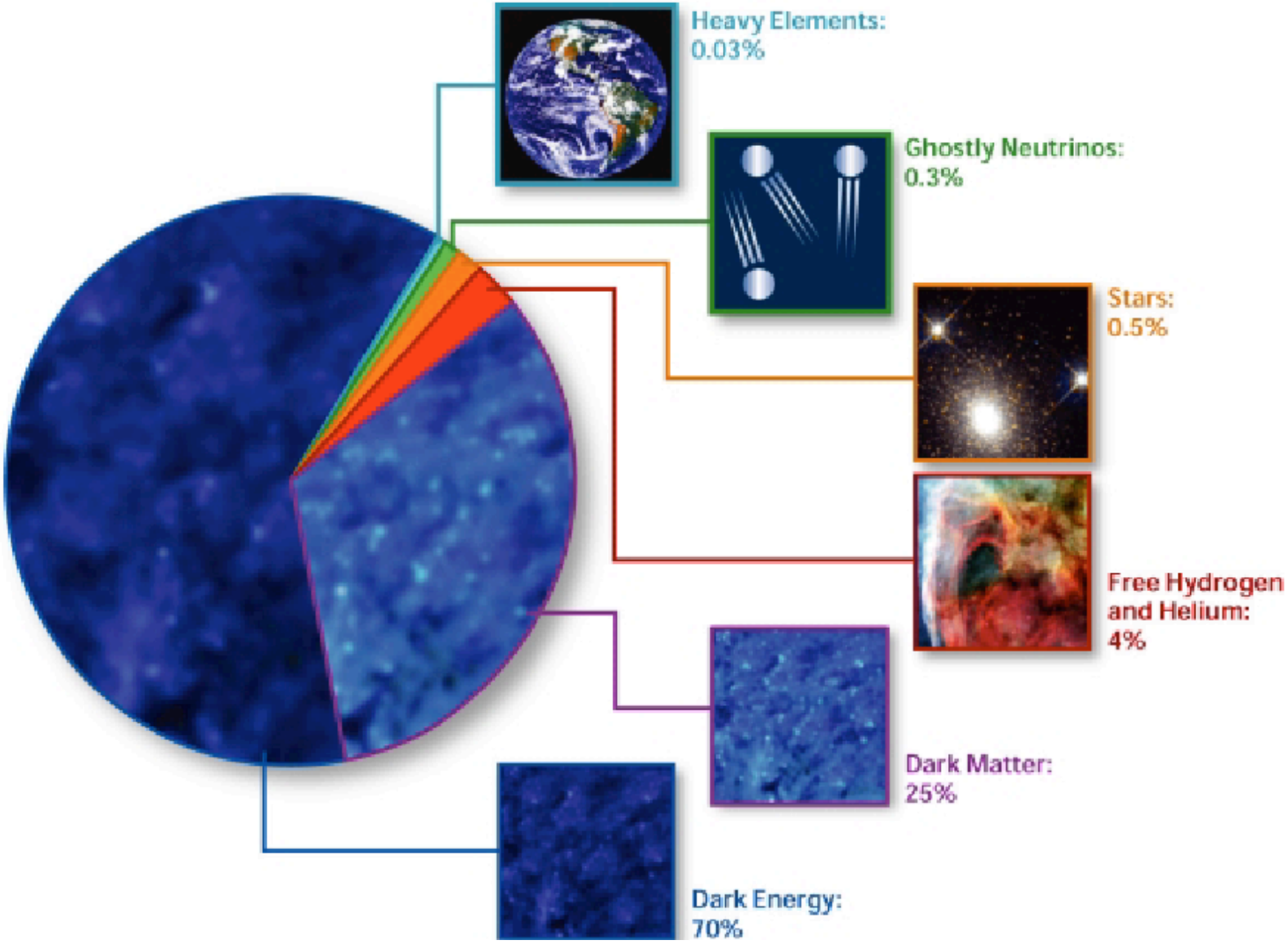
## BUT:

It is now realized that to reach the goals of particle physics it is necessary to consider the connection with the very large. Cosmology, Particle Astrophysics.



Hubble Deep Field

# What's the Matter



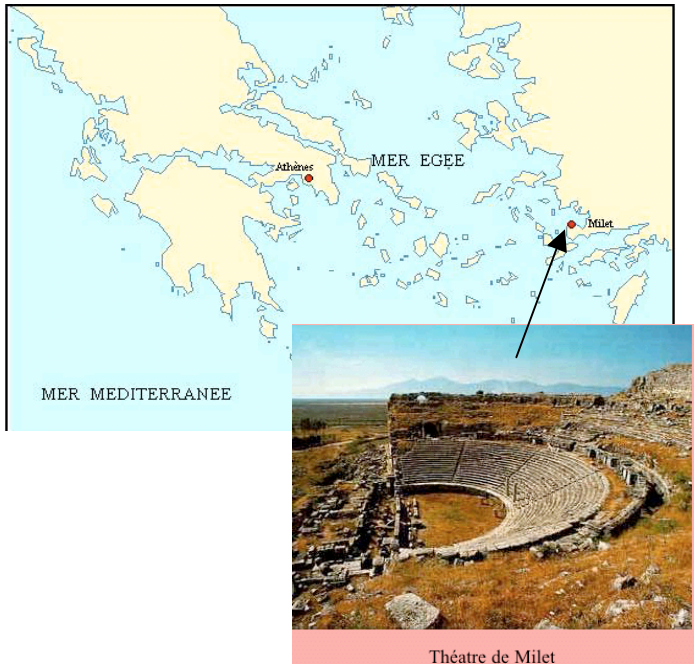
# Anaximene of Miletus
# 600 BCE
# Ionic School

Water

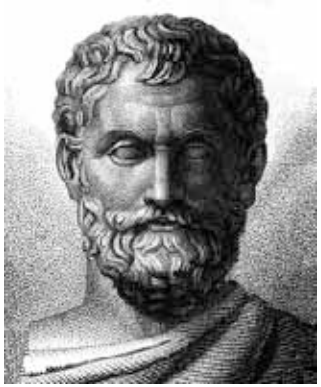
Fire

Air

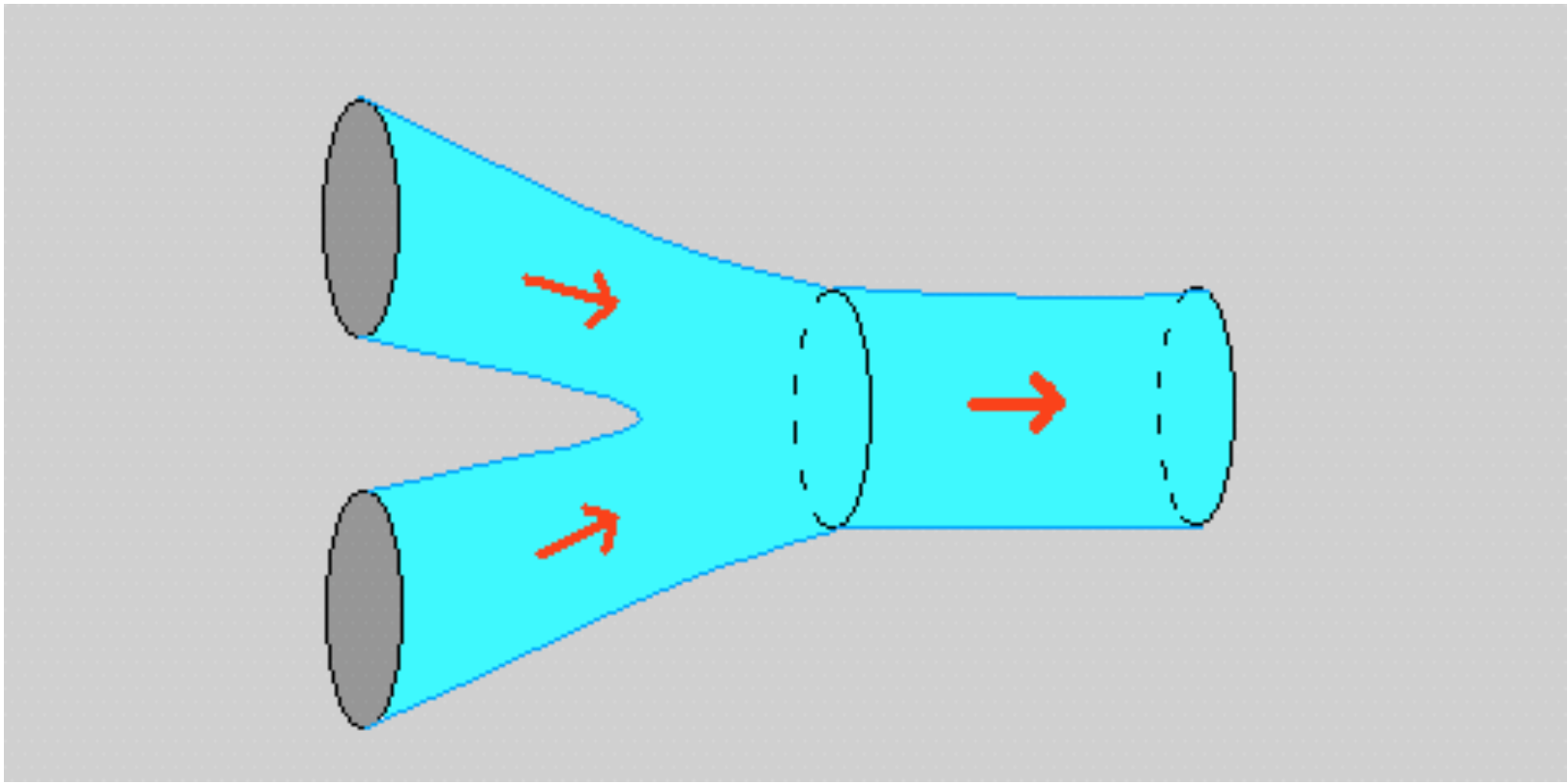
Earth




Théatre de Milet

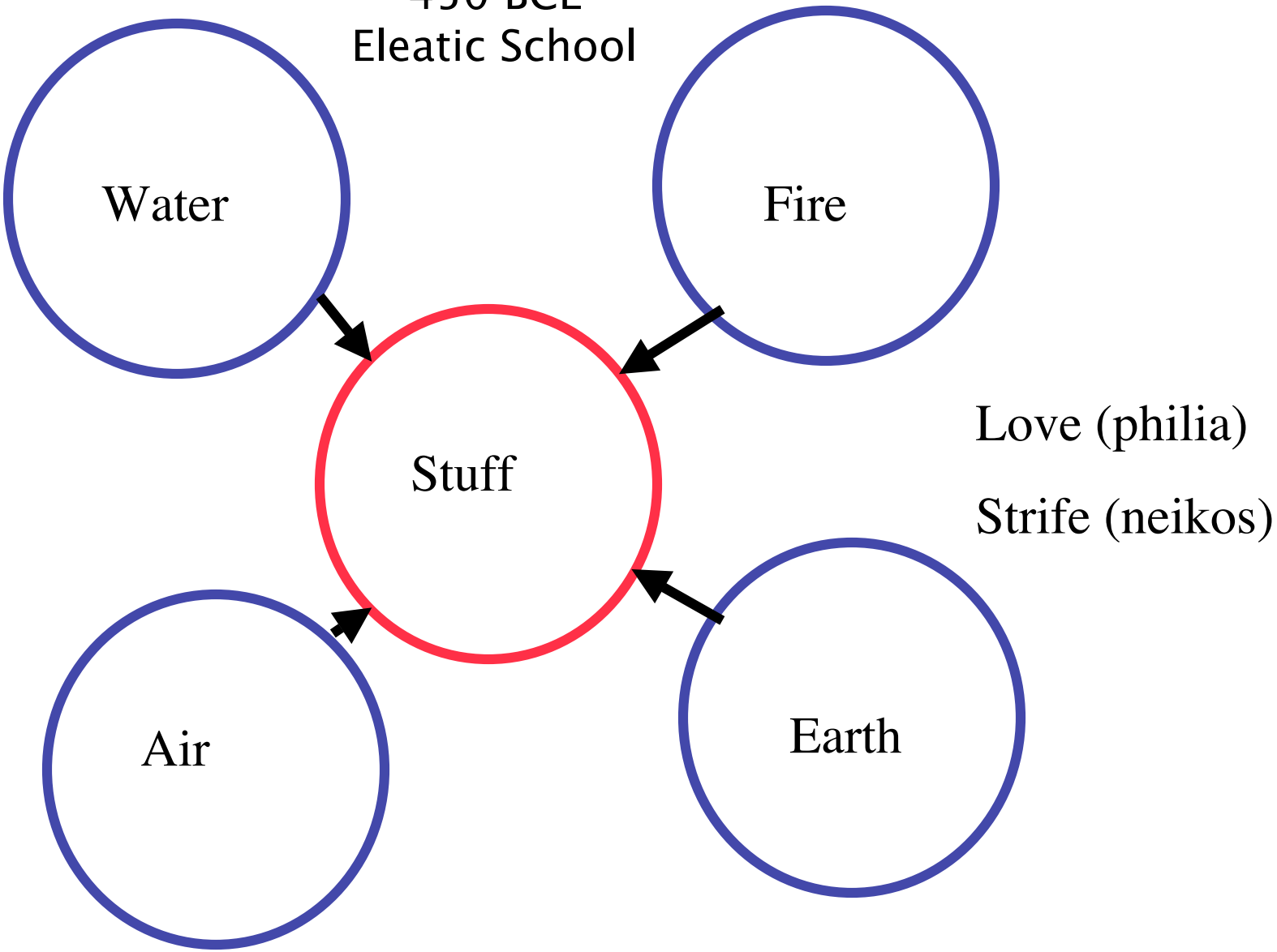


Thales



String Theory

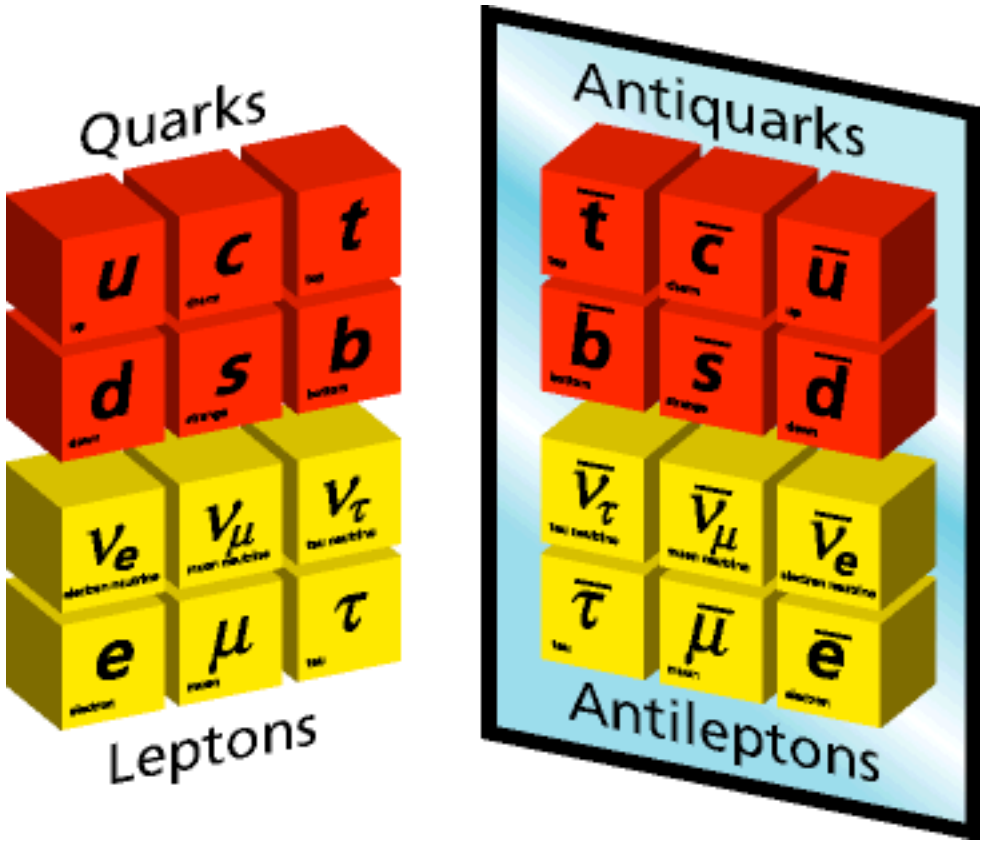
Empedocles of Acragas Sicily
450 BCE
Eleatic School




Love (philia)

Strife (neikos)

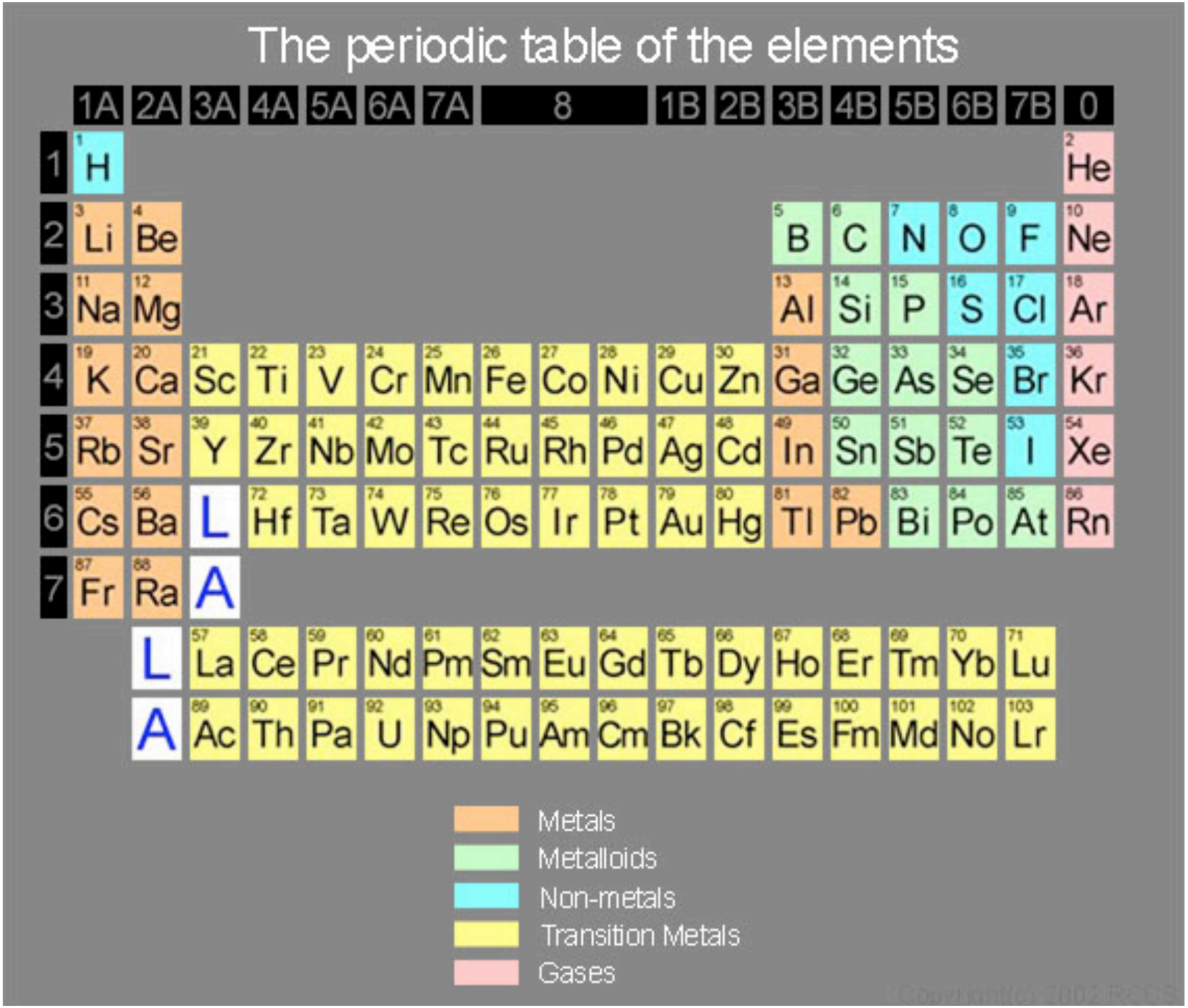
# The "Standard Model"




The word "atom" comes from the greek "a-tomos" and signifies "**indivisible**". This notion was invented by **Leucippe of Milet** in 420 before J.C.

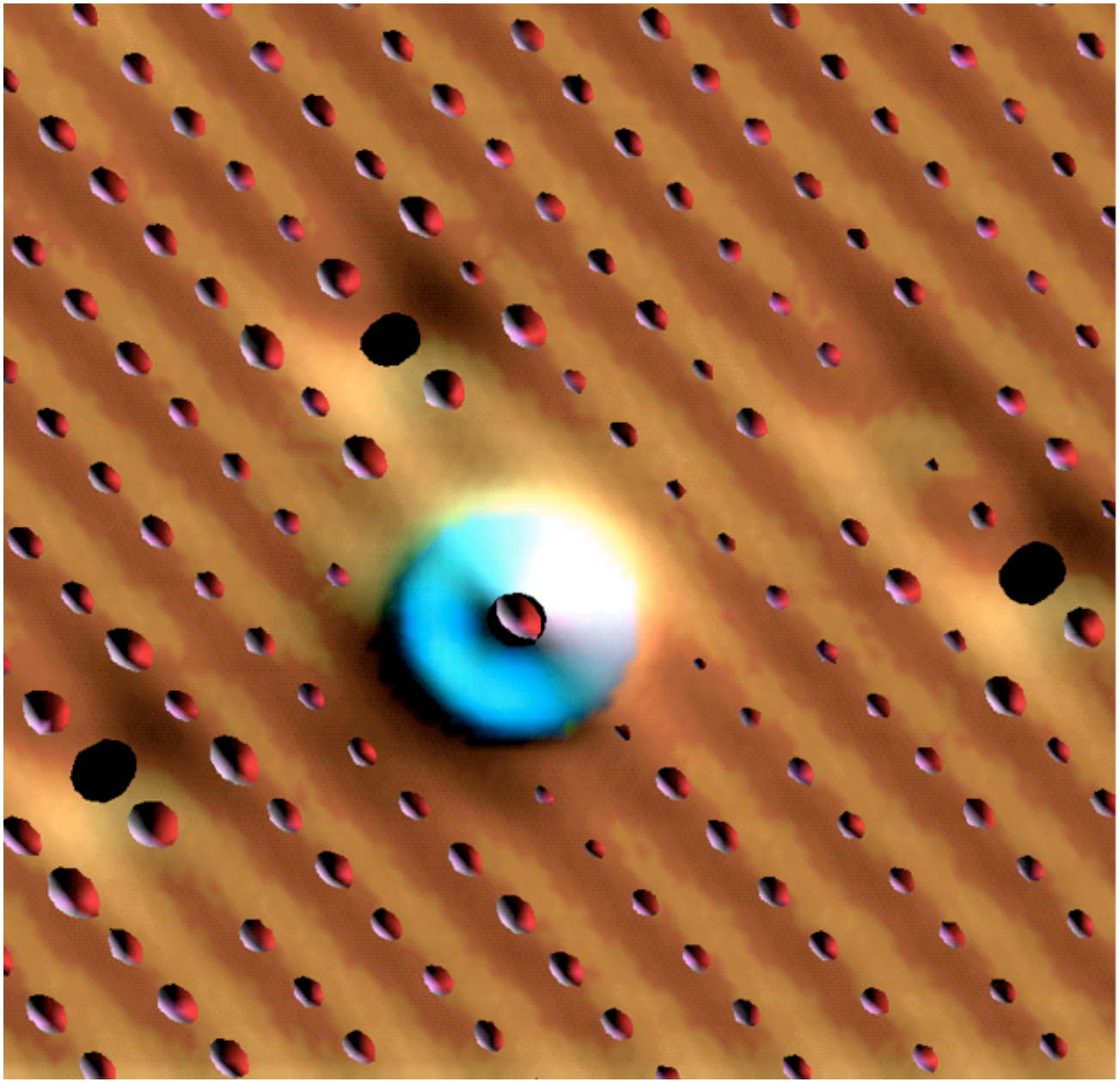
His disciple, **Democrite of Abdere** (around 460-370 BC.), explained that matter was made up of particles in perpetual motion and endowed with ideal qualities:

- invisible because of their extremely small size
- indivisible as their name indicates
- solid (no void inside)
- eternal because they are perfect
- surrounded by an empty space (to explain their movement and changes in density)
- having an infinite number of shapes (to explain the diversity observed in nature)


The periodic table of the elements
1A 2A 3A 4A 5A 6A 7A 8 1B 2B 3B 4B 5B 6B 7B 0
1 H He
2 Li Be B C N O F Ne
3 Na Mg Al Si P S Cl Ar
4 K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
5 Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
6 Cs Ba L Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
7 Fr Ra A
L La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
A Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr
Metals
Metalloids
Non-metals
Transition Metals
Gases

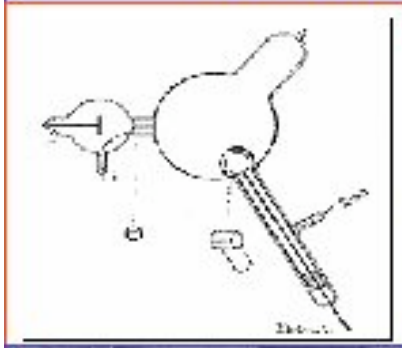
| Z | | Element | Ground-state configuration | Ground level | Ionization energy (eV) |
|---|---|---|---|---|---|
| 1 | H | Hydrogen | $1s$ | $^2S_{1/2}$ | 13.5984 |
| 2 | He | Helium | $1s^2$ | $^1S_0$ | 24.5874 |
| 3 | Li | Lithium | $1s^2\ 2s$ | $^2S_{1/2}$ | 5.3917 |
| 4 | Be | Beryllium | $1s^2\ 2s^2$ | $^1S_0$ | 9.3227 |
| 5 | B | Boron | | | |
| 6 | C | Carbo | | | |
| 7 | N | Nitrog | | | |
| 8 | O | Oxyg | | | |
| 9 | F | Fluor | | | |
| 10 | Ne | Neon | | | |
| 11 | Na | Sodiu | | | |
| 12 | Mg | Magn | | | |
| 13 | Al | Alum | | | |
| 14 | Si | Silico | | | |
| 15 | P | Phosp | | | |
| 16 | S | Sulfur | [Ne] $3s^2\ 3p^4$ | $^3P_2$ | 10.3600 |
| 17 | Cl | Chlorine | [Ne] $3s^2\ 3p^5$ | $^2P^o_{3/2}$ | 12.9676 |
| 18 | Ar | Argon | [Ne] $3s^2\ 3p^6$ | $^1S_0$ | 15.7596 |
| 19 | K | Potassium | [Ar] $4s$ | $^2S_{1/2}$ | 4.3407 |
| 20 | Ca | Calcium | [Ar] $4s^2$ | $^1S_0$ | 6.1132 |

| | | n=1 | n=2 | n=3 | n=4 |
|---|---|---|---|---|---|
| s -- sharp | $\ell = 0$ | 1s | 2s | 3s | 4s |
| p -- principal | $\ell = 1$ | | 2p | 3p | 4p |
| d -- diffuse | $\ell = 2$ | | | 3d | 4d |
| f -- fundamental | $\ell = 3$ | | | | 4f |
| g | $\ell = 4$ | beyond this point, the notation | | | |
| h | $\ell = 5$ | just follows the alphabet | | | |

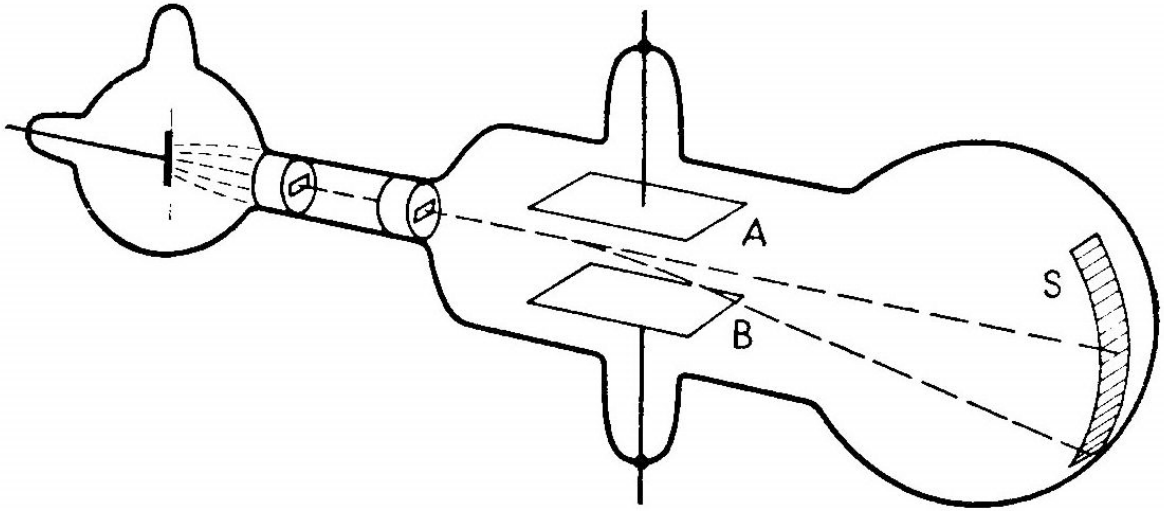


STM image of a Xeon atom sitting on top of a Nickel surface

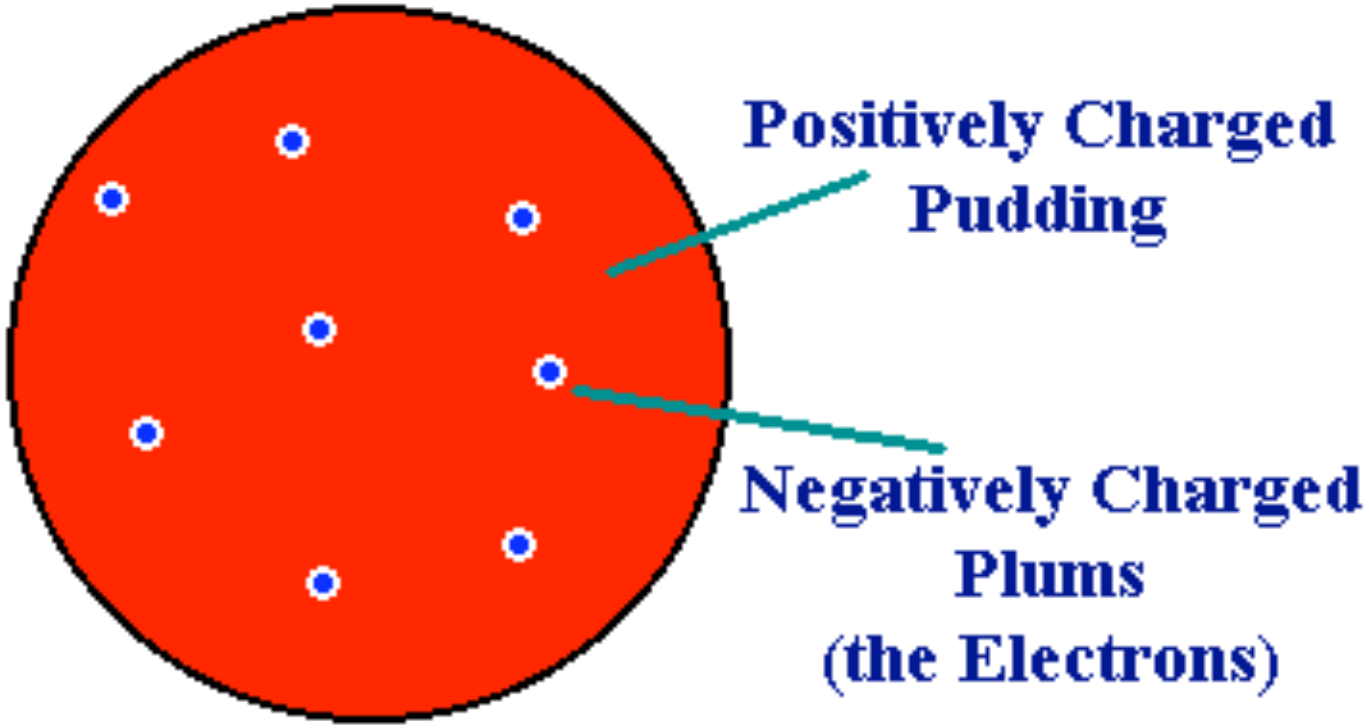
# Discovery of the Electron

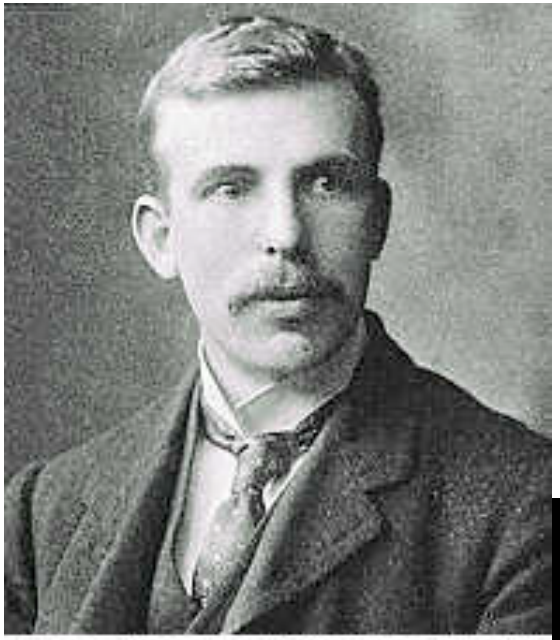


- J. J. Thompson (1856-1940) in 1897 announced discovery that cathode rays:
- 1) Had negative charge
- 2) 2000 less massive than protons.

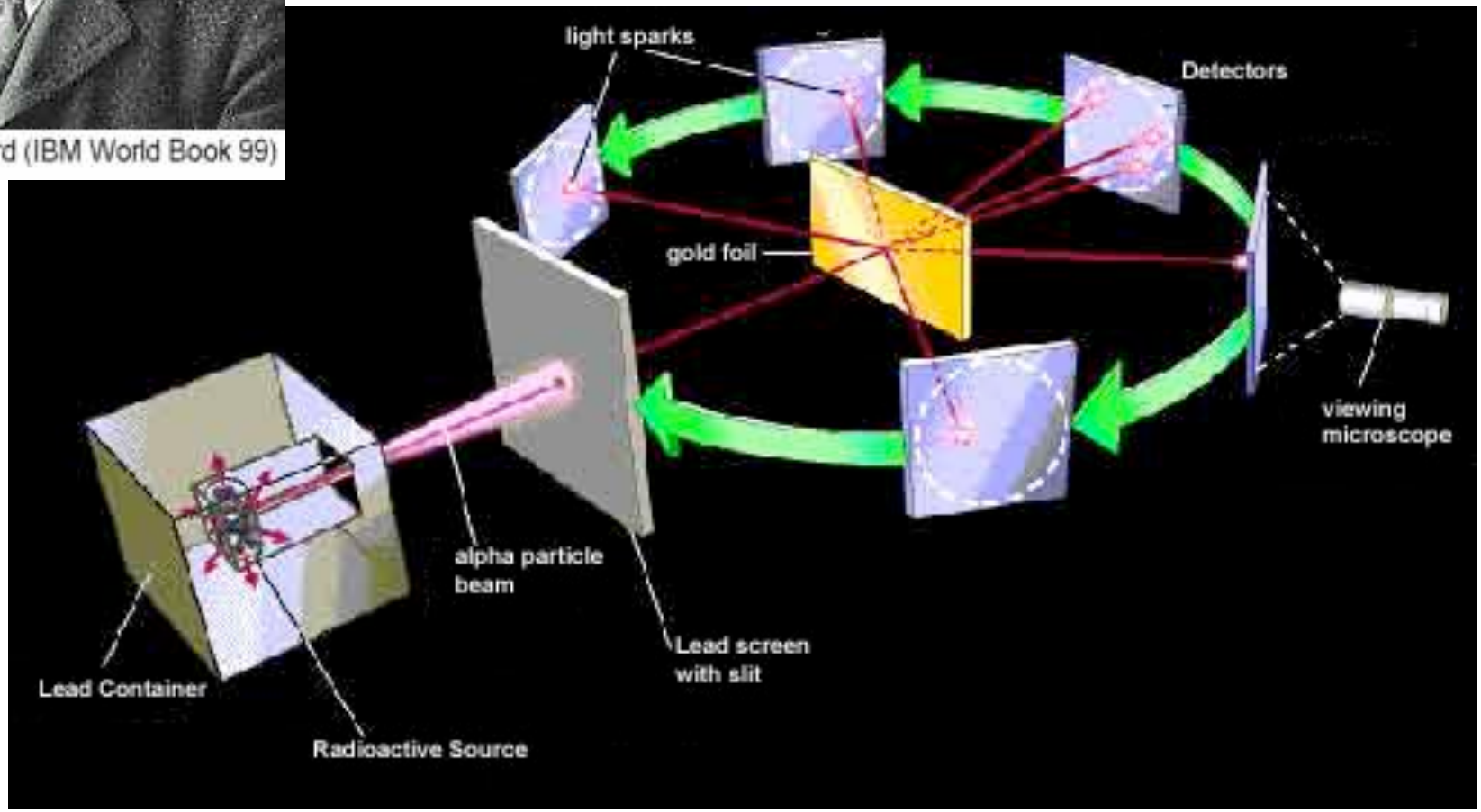


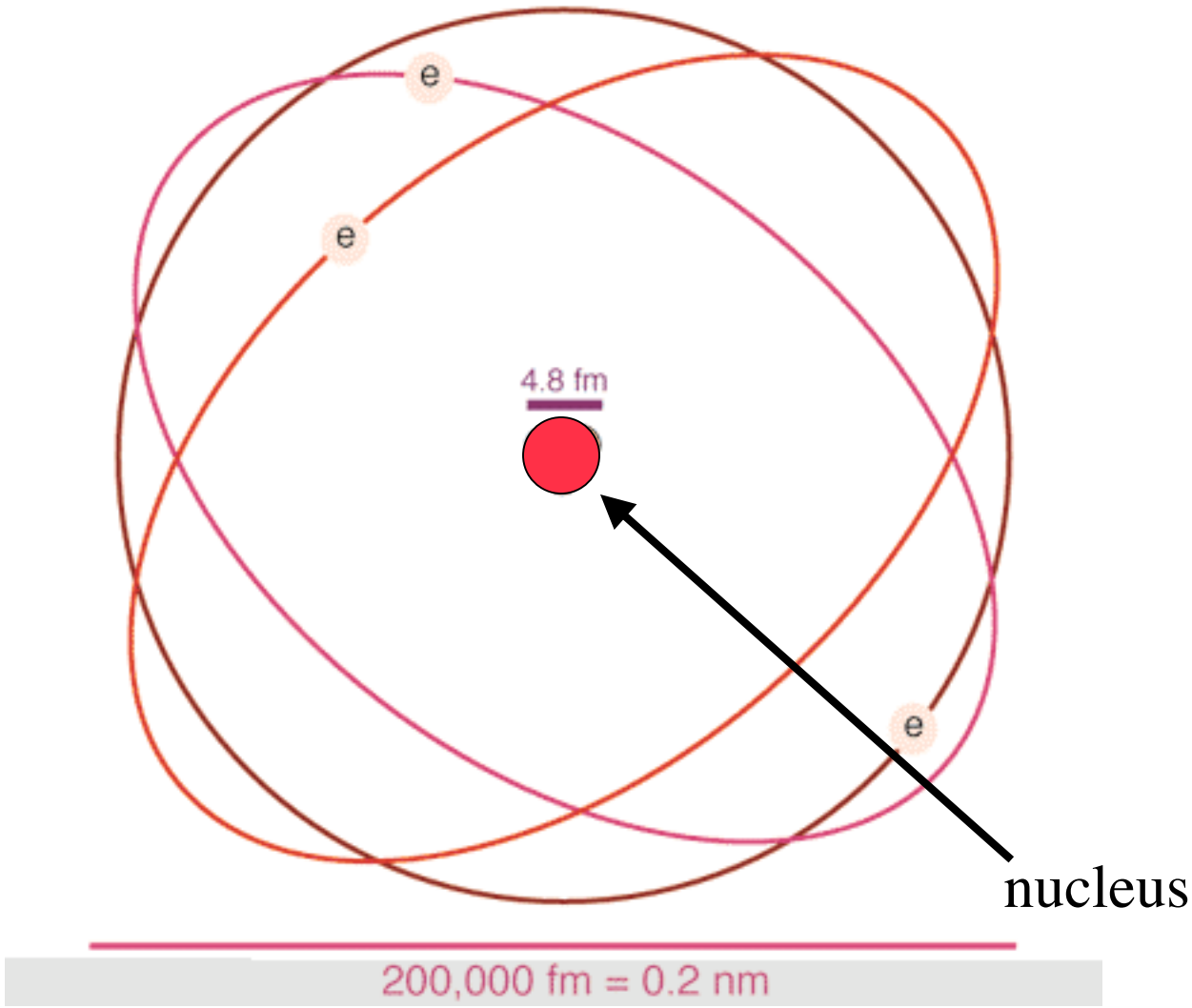
# The Plum Pudding Model





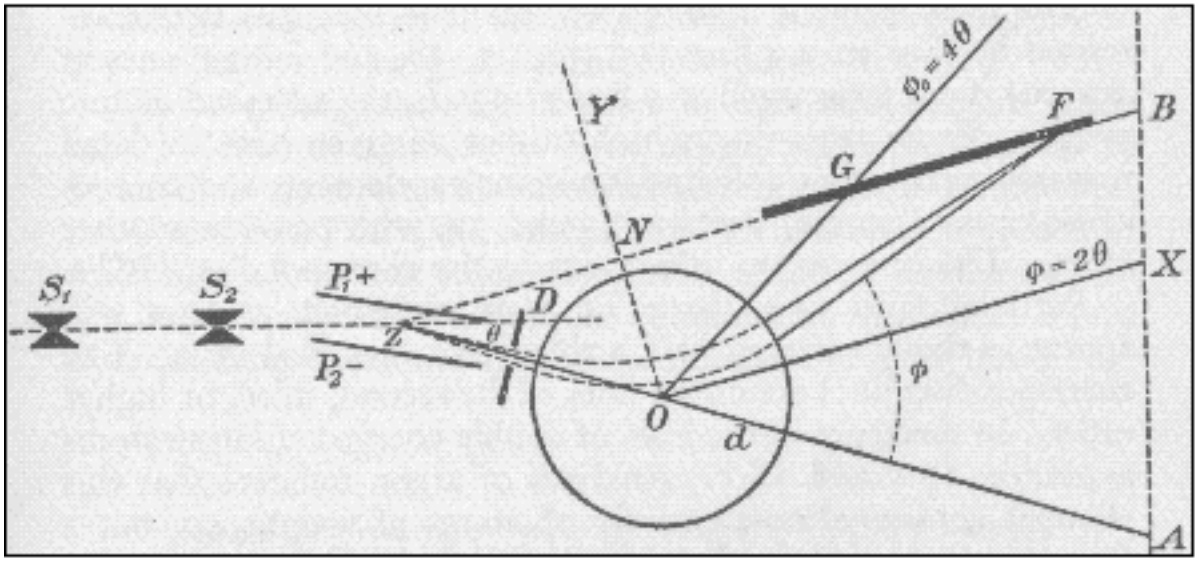
Ernest Rutherford (IBM World Book 99)






Lithium Atom


Aston’s spectrometer



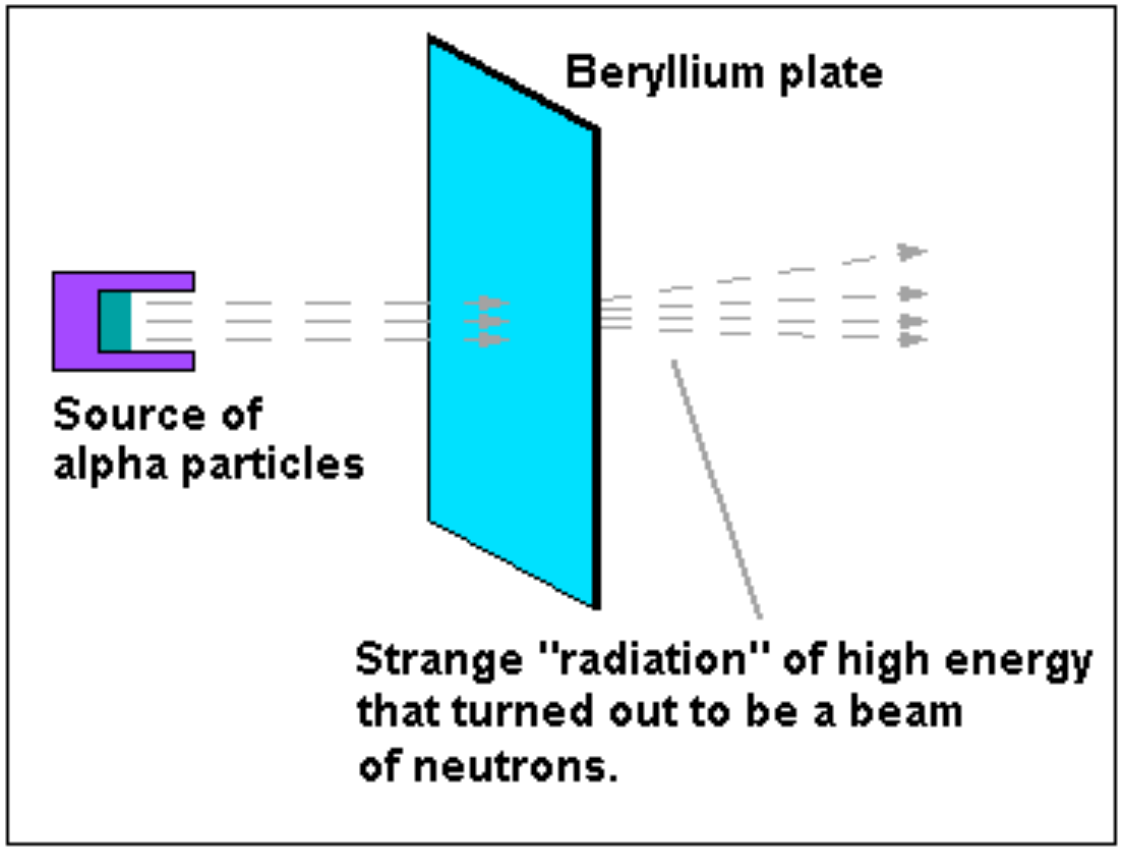

## Aston's Mass Spectograph *1919*

Whilst working at the Cavendish Laboratory in Cambridge under J J Thomson, Francis William Aston (1877-1945) undertook a series of experiments that led to the discoveries by which he is now best remembered. Aston was assigned to improving Thomson's apparatus in which a beam of positively-charged particles (positive rays) was deflected by a combination of electric and magnetic fields into sharp visible curves, each representing an individual particle's charge-to-mass ratio.

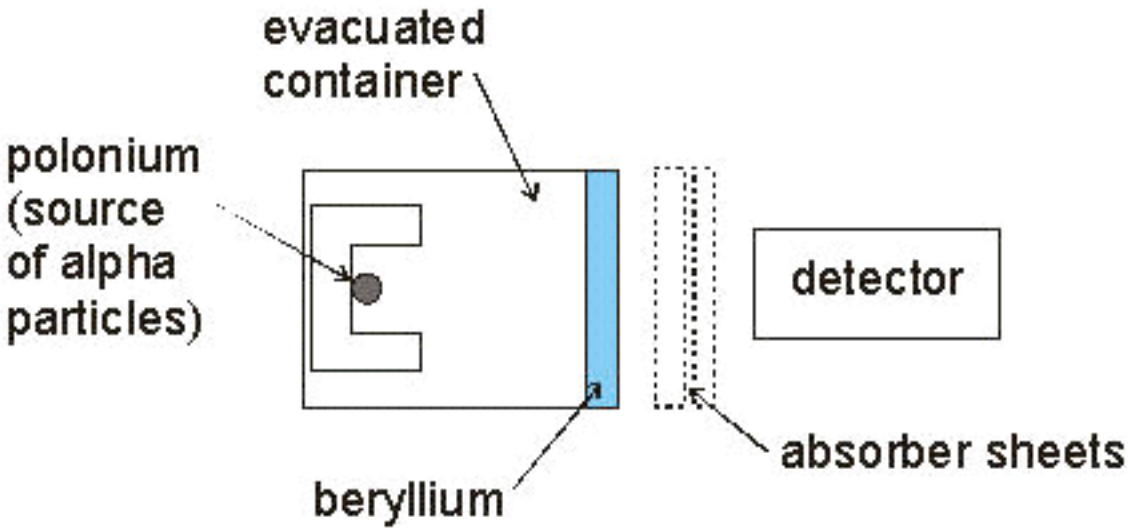
The key advance Aston made to Thomson's apparatus was his arrangement of the electric and magnetic deflecting fields so as to bring rays of uniform charge-to-mass ratio to sharp focus on a photographic plate. Aston devised several methods for calibrating his instrument and, in the case of neon, obtained mass lines on his photographic plate at 20 and 22 with the intensities of the lines showing that the two particles occurred in the ratio of 10:1, consistent with an average mass of 20.20, the known atomic weight of neon.

He had earlier shown that both masses were substances with the same properties as neon and thus neon was the first non-radioactive element proven to be isotopic (atoms with the same chemical properties, but different atomic mass).

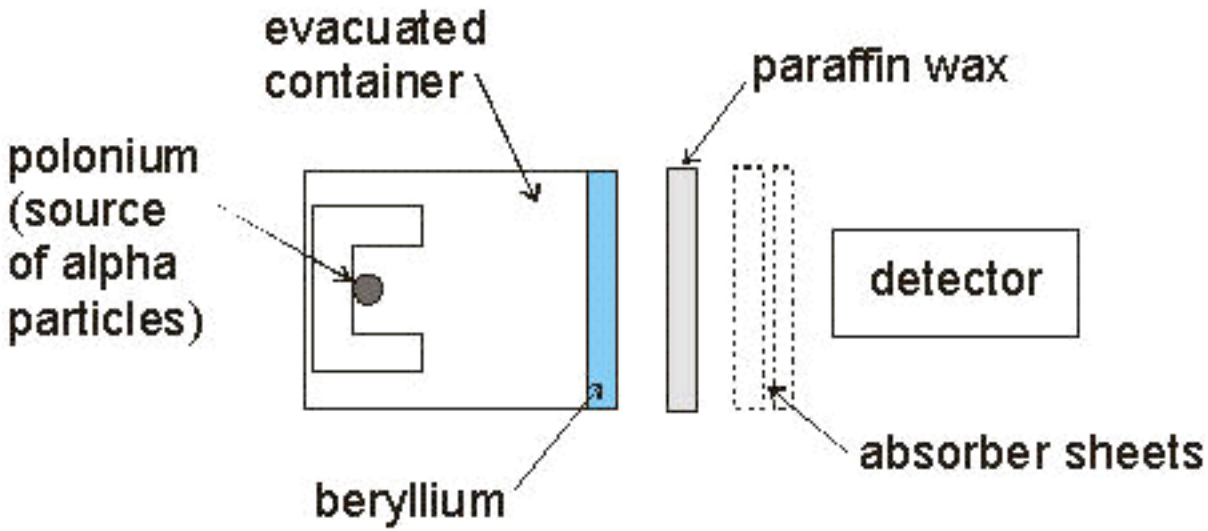
In the short time before Aston was presented with his Nobel Prize, he had demonstrated the existence of isotopes in some 30 other gaseous elements.

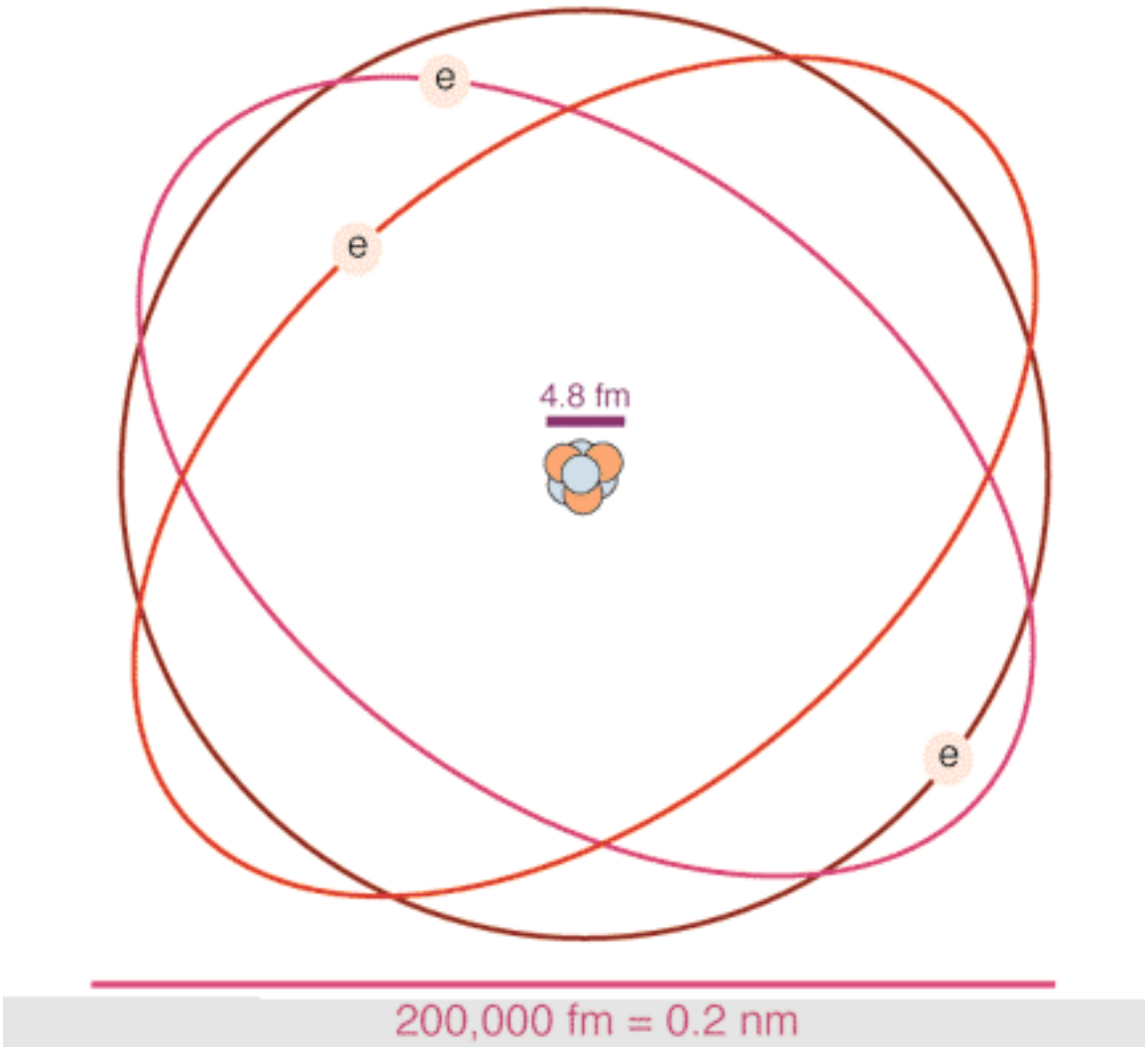



Detection of neutrons

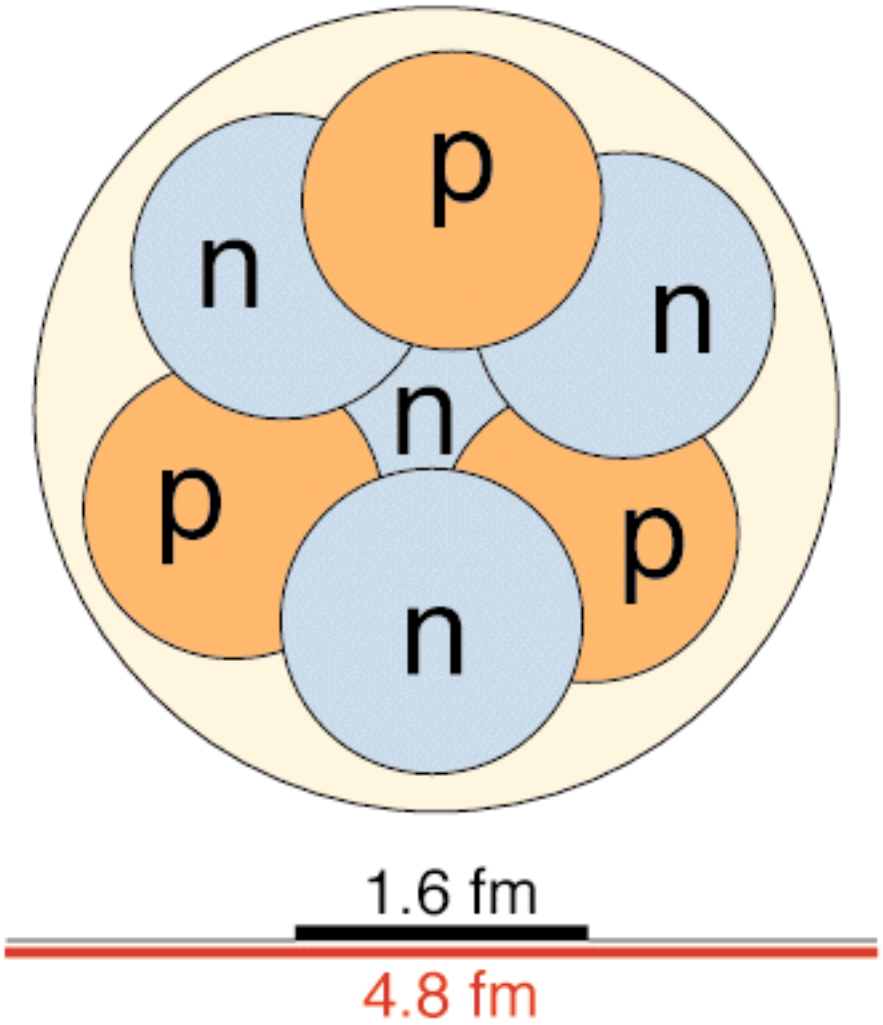



$$^{9}_{4}\mathrm{Be} + ^{4}_{2}\mathrm{He} \rightarrow ^{12}_{6}\mathrm{C} + ^{1}_{0}\mathrm{n}$$

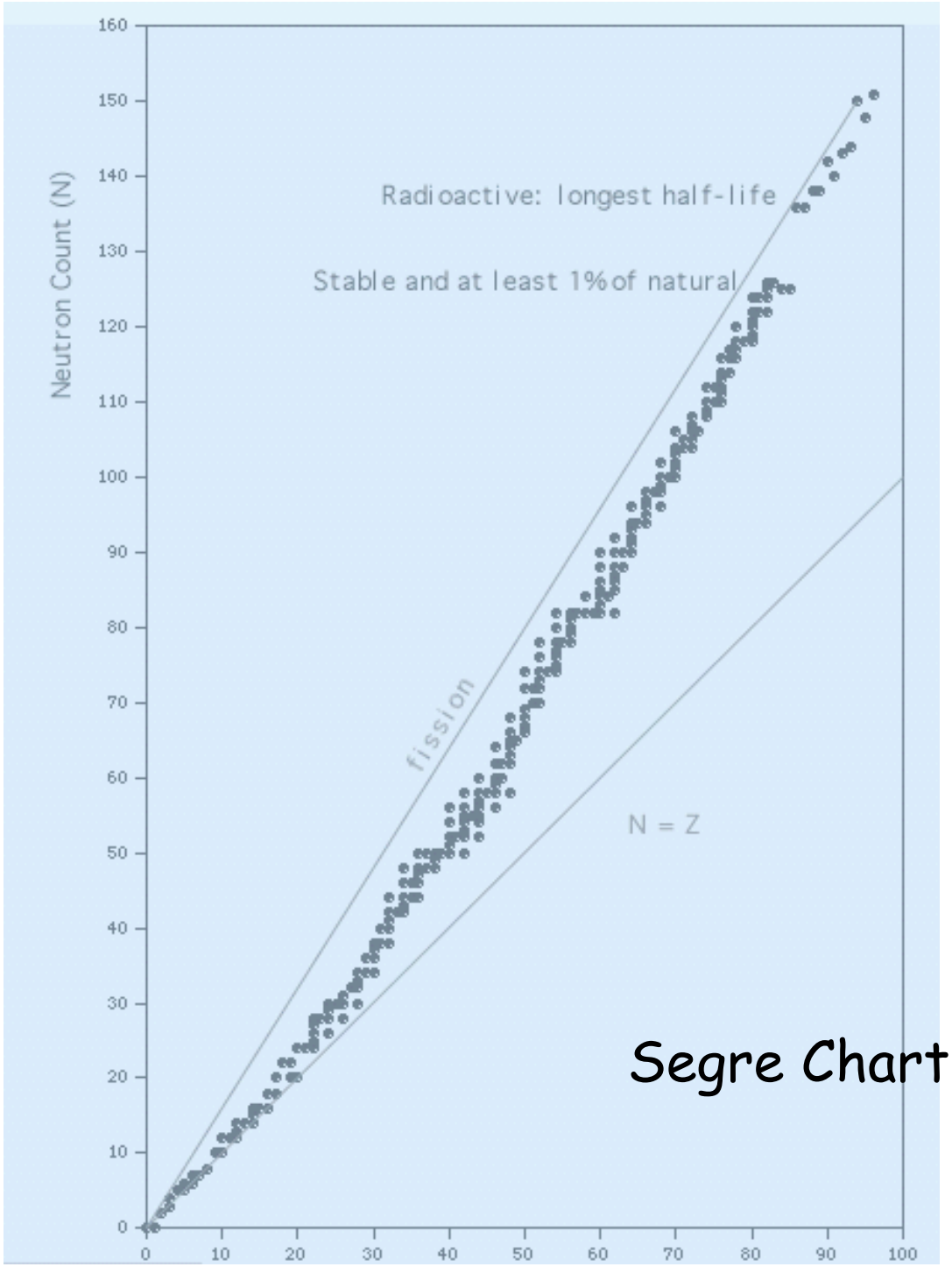





Lithium Atom



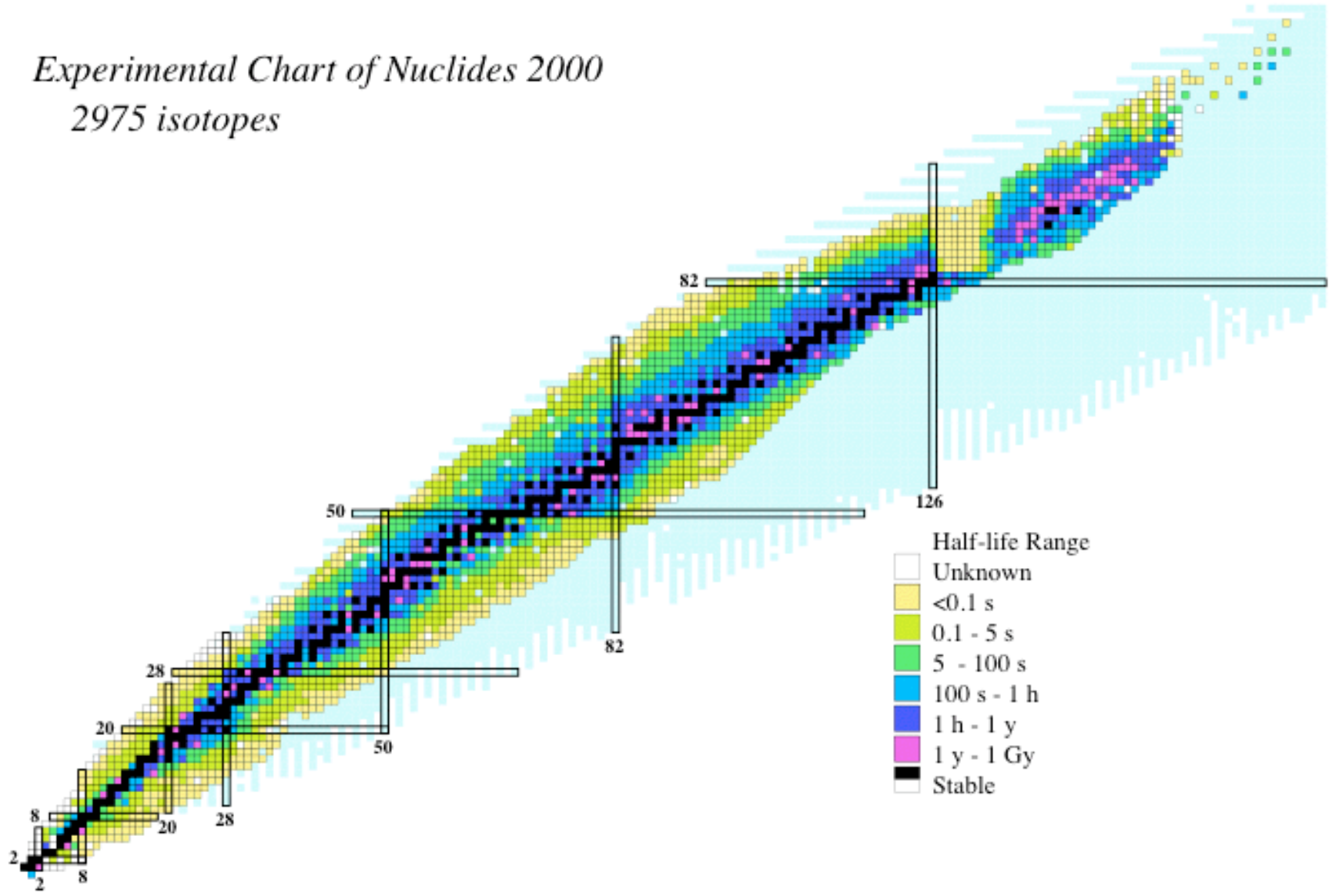

$^{7}$Li Nucleus


Neutron Count (N)
Radioactive: longest half-life
Stable and at least 1% of natural
fission
N = Z
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

Segre Chart

*Experimental Chart of Nuclides 2000*

*2975 isotopes*



# Beta Decay

$$M_{parent}c^2 \Rightarrow E_{daughter} + E_{electron}$$

$$KE_{electron} \approx M_{parent}c^2 - M_{daughter}c^2 - m_{electron}c^2$$

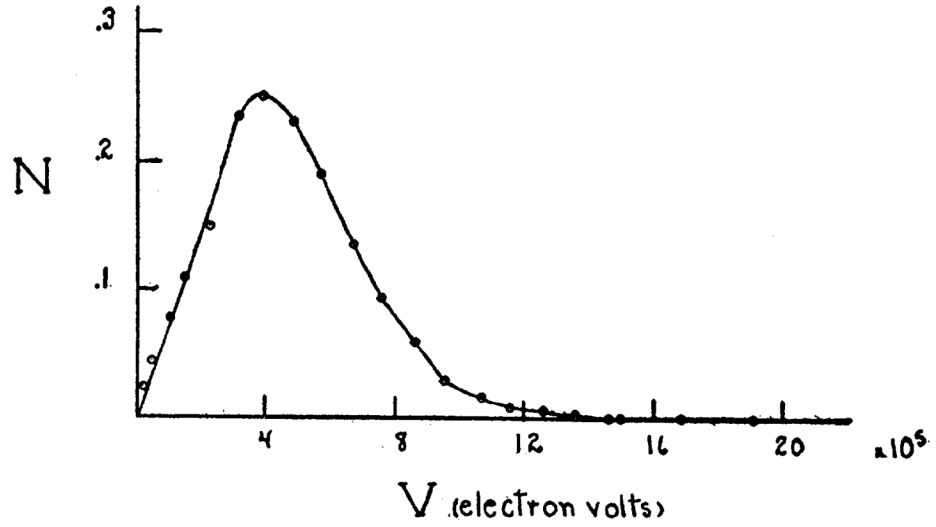
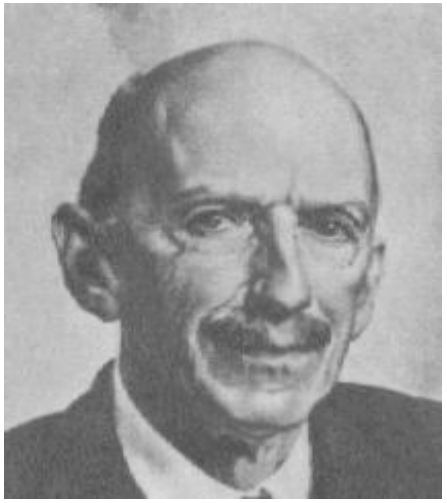
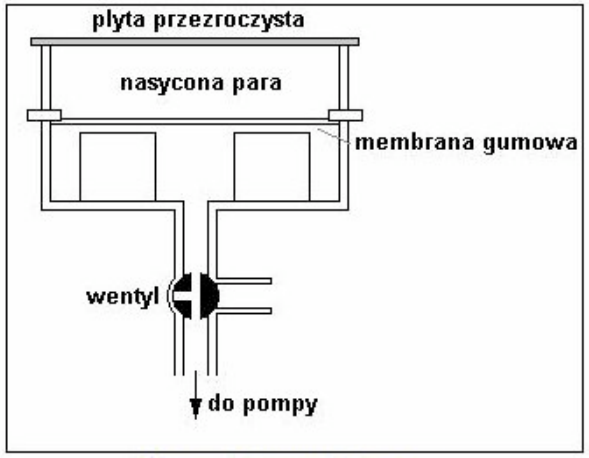



FIG. 5. Energy distribution curve of the beta-rays.

## Continuous Beta Spectrum






Schemat komory Wilsona.

# Wilson Cloud Chamber

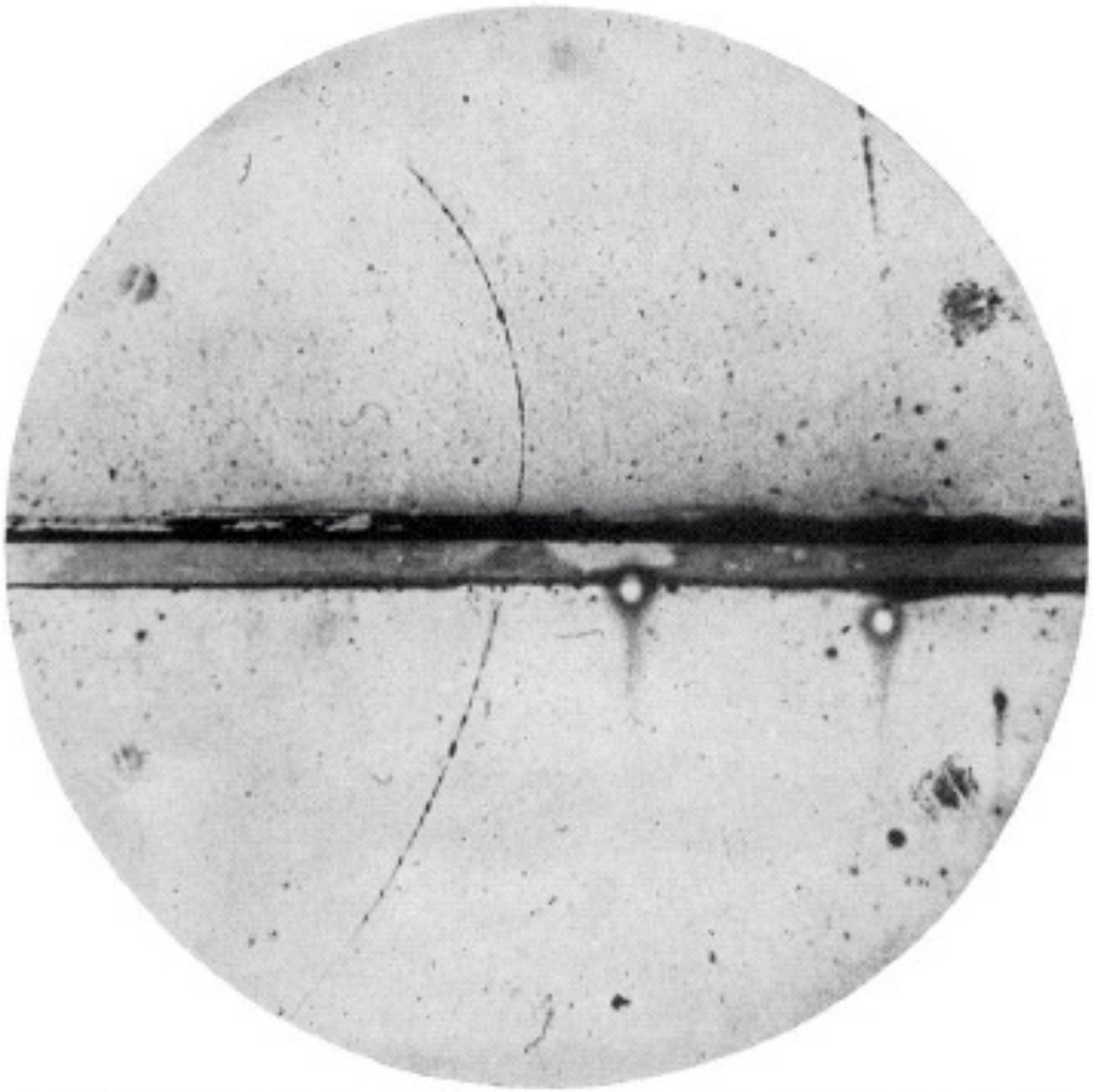
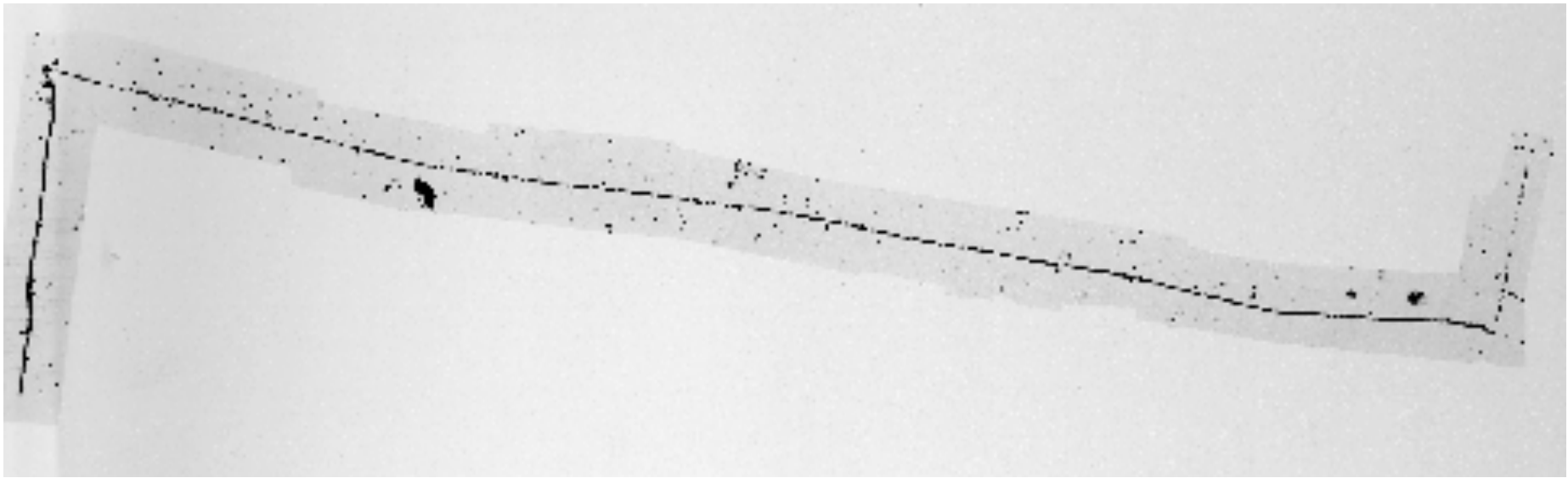
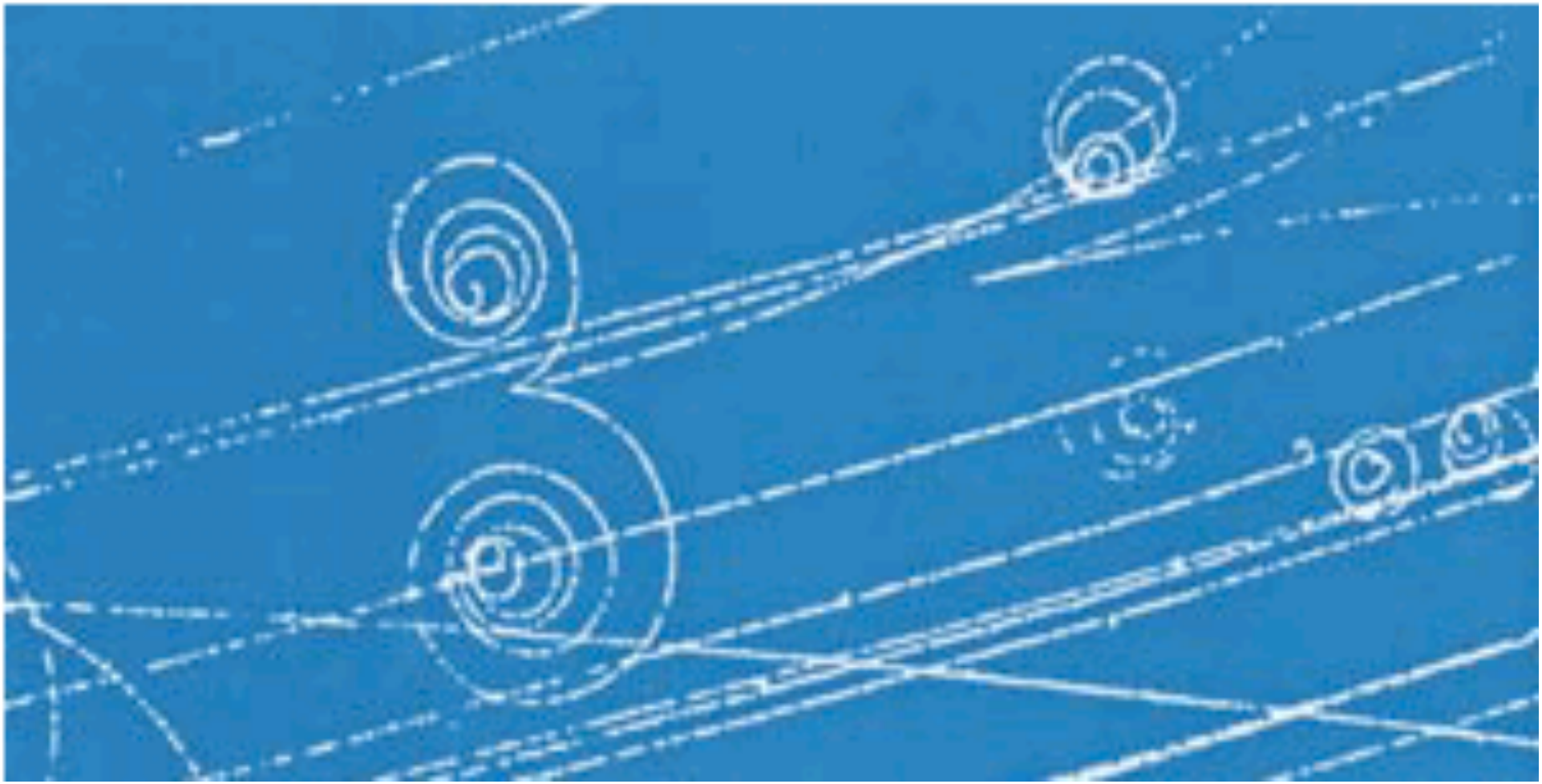
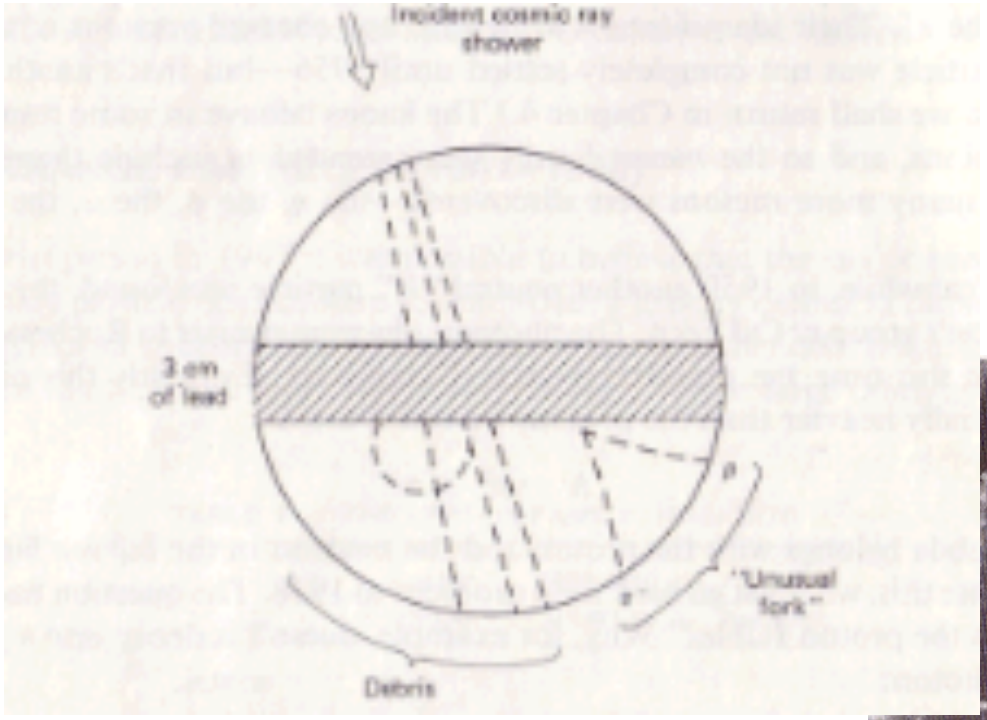


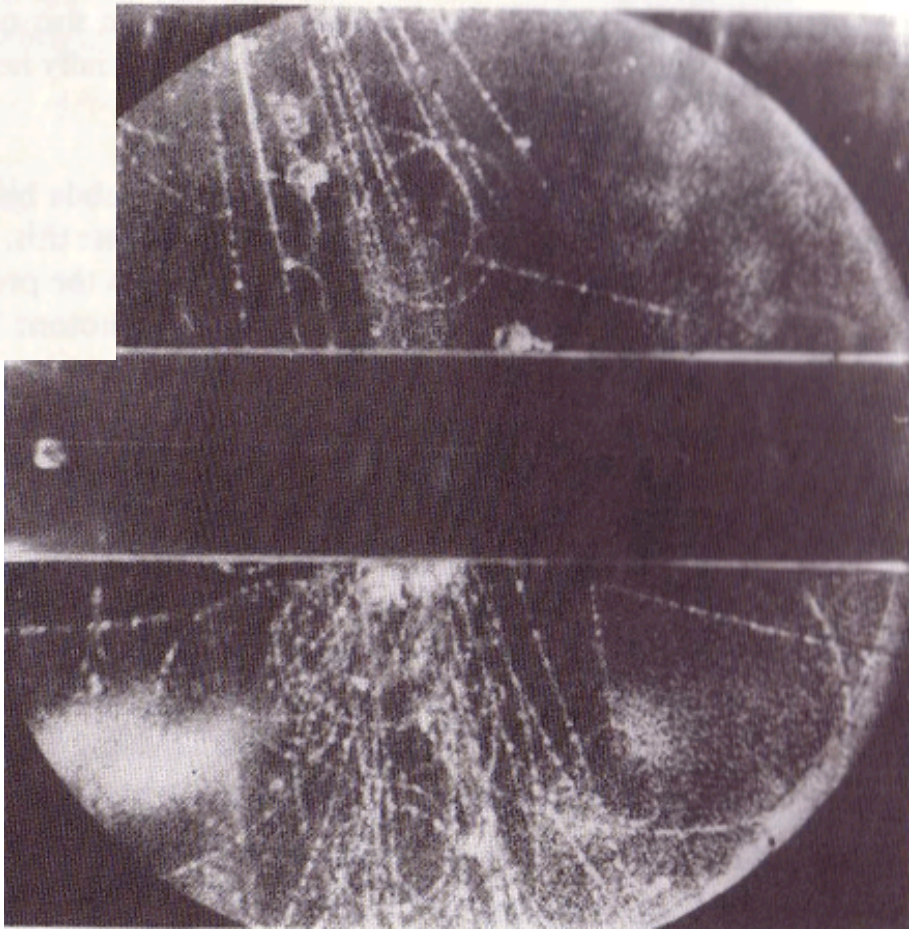
FIG. 1. A 63 million volt positron ($H\rho = 2.1 \times 10^5$ gauss-cm) passing through a 6 mm lead plate and emerging as a 23 million volt positron ($H\rho = 7.5 \times 10^4$ gauss-cm). The length of this latter path is at least ten times greater than the possible length of a proton path of this curvature.



Discovery of the pion

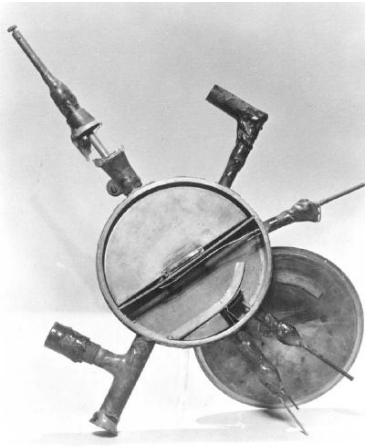


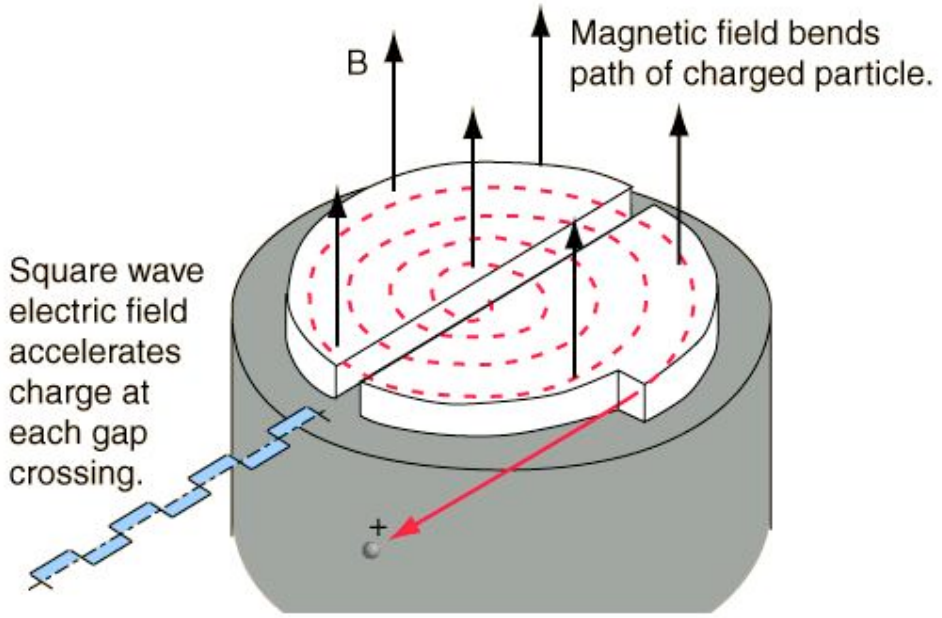


First Strange Particle

Lawrence






The Cyclotron

Segre

Chamberlain

Bevatron